

**ALABAMA  
Highway 199**

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**ALABAMA  
Highway 199****1. DESCRIPTION**

Location:	Highway 199 over Uphapee Creek, Macon County
Open to Traffic:	April 2000
Environment:	Normal over water
HPC Elements:	Substructure, girders, and deck
Total Length:	798 ft
Skew or Curve:	—
Girder Type:	BT-54
Span Lengths:	Seven spans of 114 ft
Girder Spacing:	8 ft 9 in
Girder Strand Grade:	270
Girder Strand Dia.:	0.6 in
Max. No. of Bottom Strands:	50
Deck Thickness:	7 in
Deck Panels:	None

## 2. BENEFITS OF HPC AND COSTS

### A. Benefits of HPC

The original design for the bridge was made using conventional strength concrete and resulted in eight spans of 100 ft using six lines of BT-54 girders. The use of HPC resulted in the elimination of 810 ft of BT-54 girders for an estimated cost savings of \$100,000. Additionally, the use of HPC resulted in one less pier at an estimated savings of \$100,000. Consequently, total savings were approximately \$200,000 less the added cost of the HPC. Bid analysis results did not indicate any significant price increase for furnishing HPC. The anticipated benefits with the use of HPC are twofold. One is a saving on initial construction costs from the use of one less girder line and one less pier. The second is the anticipation of a more durable concrete structure resulting in less maintenance costs and a longer service life.

### B. Costs

Substructure Concrete (6000 psi):	\$325/yd <sup>3</sup>
Superstructure Concrete (6000 psi):	\$288.83/yd <sup>3</sup>
AASHTO BT-54:	\$120/linear ft
Substructure Cost:	\$24.72/ft <sup>2</sup> of deck surface area
Superstructure Cost:	\$16.93/ft <sup>2</sup> of deck surface area
Total Low Bid:	\$3,464,000

### 3. STRUCTURAL DESIGN

Design Specifications:	—
Design Live Loads:	—
Seismic Requirements:	—
Flexural Design Method:	—
Maximum Compressive Strain:	—
Shear Design Method:	—
Fatigue Design Method:	—
Lateral Stability Considerations:	—
Allowable Tensile Stress	
—Top of Girder at Release:	—
—Bottom of Girder after Losses:	—
Prestress Loss:	—
Method Used for Loss:	—
Calculated Camber:	—
Concrete Cover	
—Girder:	—
—Top of Deck:	2 in clear
—Bottom of Deck:	1 in clear
—Other Locations:	—
Properties of Reinforcing Steel	
—Girder:	—
—Deck:	—
Properties of Strand	
—Grade and Type:	Grade 270, low relaxation
—Supplier:	—
—Surface Condition:	—
—Pattern:	Draped
—Transfer Length:	—
—Development Length:	—

## 4. SPECIFIED ITEMS

### A. Concrete Properties

	<u>Girders</u>	<u>CIP Concrete</u>
Minimum Cementitious Materials Content:	—	—
Max. Water/Cementitious Materials Ratio:	0.32	0.40
Min. Percentage of Class F Fly Ash:	15	15
Max. Percentage of Class F Fly Ash:	25	25
Min. Percentage of Class C Fly Ash:	15	20
Max. Percentage of Class C Fly Ash:	35	30
Min. Percentage of Silica Fume:	7	7
Max. Percentage of Silica Fume:	15	15
Min. Percentage of GGBFS:	—	—
Max. Percentage of GGBFS:	—	—
Maximum Aggregate Size:	—	—
Slump:	≤ 8.0 in	≤ 5 in for superstructure ≤ 8 in for substructure
Air Content:	3.5-6.0%	3.5-6.0%
Compressive Strength		
—Release of Strands:	8000 psi	—
—Design:	10,000 psi at 28 days	6000 psi at 28 days
Chloride Permeability: (AASHTO T 277)	—	—
ASR or DEF Prevention:	—	—
Freeze-Thaw Resistance:	—	—
Deicer Scaling:	—	—
Abrasion Resistance:	—	—
Other:	—	Maximum temperature of fresh concrete = 95 °F. Crushed limestone # 57 or # 67 as coarse aggregate.

**B. Specified QC Procedures****Girder Production**

Curing:	Intermittent or partial steam
Internal Concrete Temperature:	160 °F max.
Cylinder Curing:	Match cure within 5 °F of product until release. After release, cure the same as the girders.
Cylinder Size:	6x12 in or 4x8 in
Cylinder Capping Procedure:	—
Cylinder Testing Method:	—
Frequency of Testing:	Twelve cylinders for every 50 yd <sup>3</sup>
Other QA/QC Requirements:	Monitor internal temperature at three locations. Trial placement consisting of full cross section of girder at least 10-ft long in the planned casting bed.

**Deck Construction**

Curing:	Wet curing for 7 days
Cylinder Curing:	Maintained at 60 to 80 °F for 48 hours maximum
Cylinder Size:	6x12 in or 4x8 in
Flexural Strength:	—
Other QA/QC Requirements:	Concrete temperature at time of placement between 50 and 95° F. Test pour at least 4-in thick and 400 ft <sup>2</sup> surface area.

## 5. CONCRETE MATERIALS

### A. Approved Concrete Mix Proportions

	<u>Girders</u>	CIP <u>Superstructure</u>	CIP <u>Substructure</u>
Cement Brand:	—	Blue Circle	Holman
Cement Type:	III	II	II
Cement Composition:	—	—	—
Cement Fineness:	—	—	—
Cement Quantity:	753 lb/yd <sup>3</sup>	658 lb/yd <sup>3</sup>	640 lb/yd <sup>3</sup>
GGBFS Brand:	—	—	—
GGBFS Quantity:	—	—	—
Fly Ash Brand:	—	—	—
Fly Ash Type:	C	C	—
Fly Ash Quantity:	133 lb/yd <sup>3</sup>	165 lb/yd <sup>3</sup>	160lb/yd <sup>3</sup>
Silica Fume Brand:	—	—	—
Silica Fume Quantity:	—	—	—
Fine Aggregate 1. Type:	Natural sand	Natural sand	Natural sand
Fine Aggregate 1. FM:	—	—	—
Fine Aggregate 1. SG:	—	—	—
Fine Aggregate 1. Quantity:	695 lb/yd <sup>3</sup>	1042 lb/yd <sup>3</sup>	990 lb/yd <sup>3</sup>
Fine Aggregate 2. Type:	Natural sand	—	—
Fine Aggregate 2. FM:	—	—	—
Fine Aggregate 2. SG:	—	—	—
Fine Aggregate 2. Quantity:	374 lb/yd <sup>3</sup>	—	—
Coarse Aggregate, Max. Size:	3/4 in (1)	1 in	—
Coarse Aggregate Type:	No. 67 crushed limestone (2)	Crushed limestone	Crushed limestone
Coarse Aggregate SG:	—	—	—
Coarse Aggregate Quantity:	1916 lb/yd <sup>3</sup>	1860 lb/yd <sup>3</sup>	1950 lb/yd <sup>3</sup>
Water:	248 lb/yd <sup>3</sup>	288 lb/yd <sup>3</sup>	300 lb/yd <sup>3</sup>
Water Reducer Brand:	Delvo	MB Pozzolith 100-XR	—
Water Reducer Type:	B and D	B and D	—
Water Reducer Quantity:	75 fl oz/yd <sup>3</sup>	25 fl oz/yd <sup>3</sup>	25 fl oz/yd <sup>3</sup>
High-Range Water-Reducer Brand:	Rheobuild 1000	Polyheed 977	—
High-Range Water-Reducer Type:	A and F	A and F	—
High-Range Water-Reducer Quantity:	225 fl oz/yd <sup>3</sup>	98 fl oz/yd <sup>3</sup>	96 fl oz/yd <sup>3</sup>
Retarder Brand:	—	—	—
Retarder Type:	—	—	—
Retarder Quantity:	—	—	—
Corrosion Inhibitor Brand:	—	—	—
Corrosion Inhibitor Type:	—	—	—
Corrosion Inhibitor Quantity:	—	—	—
Air Entrainment Brand:	Micro Air	MB AE90	—
Air Entrainment Type:	Surfactant	Anionic Surfactant	—

Air Entrainment Quantity:	35 fl oz/yd <sup>3</sup>	32 fl oz/yd <sup>3</sup>	32 fl oz/yd <sup>3</sup>
Water/Cementitious Materials Ratio:	0.28	0.37	0.38
(1) Later changed to 1/2 in.			
(2) Later changed to No. 7 limestone.			

**B. Measured Properties of Approved Mix**

	<u>Girders</u>	<u>Deck</u>
Slump:	—	—
Air Content:	—	—
Unit Weight:	—	—
Compressive Strength:	—	—
Chloride Permeability: (AASHTO T 277)	—	—



## 6. CONCRETE MATERIAL PROPERTIES

### A. Measured Properties from QC Tests of Production Concrete for Girders

Cement Composition: —  
 Actual Curing Procedure for Girders: Intermittent steam  
 Slump and Air Content:

Pour No.	Slump, in		Air Content, %	
	1 (3)	2 (3)	1 (3)	2 (3)
1	7	6	3.8	3.5
2	8-1/2	9	4.6	5.4
3	8-1/2	5-1/4	4.5	3.9
4	8	7	5.0	5.0
5	8-1/4	8-1/4	4.9	4.8
6	5-1/2	8-3/4	3.8	4.6
7	8	8	4.2	4.4
8	7-1/2	8-1/4	3.6	4.1
9	7-3/4	8-1/2	4.1	5.2
10	8-1/2	8	4.0	3.8
11	7-1/2	8	3.6	3.6
12	8	7-1/2	3.7	4.2
13	8-1/2	8	5.1	4.1
14	7	7-3/4	4.6	4.7
15	8	4-3/4	6.0	4.0
16	7	7-1/2	5.2	5.1
17	8-3/4	8-1/4	5.2	4.5
18	7-1/2	8-1/4	4.8	4.5
Average	7-3/4		4.4	

(3) Measured on first batch of concrete and on a second batch of concrete after the first 50 yd<sup>3</sup>.

## Compressive Strength:

Pour No. (4)	Release Time, hours	Compressive Strength(5), psi			
		Release	28 days	56 days	Core (6)
1	24	8080	9890	10,110	9730
2	42	8080	8440	9610	8200
3	19	8240	10,240	10,720	—
4	22	8080	9750	9470	9450
5	20.5	8300	10,060	10,360	—
6	22	8120	9210	8440	9720
7	5 days	8160	8540	8600	8950
8	21.5	8830	10,000	10,180	—
9	20.5	8040	9710	9550	8450
10	19.5	8480	9830	9670	10,030
11	20	8080	10,030	9710	—
12	45	8360	8950	8620	9530
13	21	9130	10,820	10,320	—
14	21	8680	10,250	8980	—
15	19	9370	11,060	11,320	—
16	20	8340	10,260	10,540	—
17	20	9450	10,900	11,380	—
18	22	9810	10,660	11,600	—
Average		8540	9920	9950	9260

(4) No. 67 limestone used in pours 1 through 12, No. 7 limestone used in pours 13 through 18.

(5) Average of two 4x8-in Sure Cure cylinders tested using sulfur caps.

(6) Core testing was conducted if the required 28-day strength was not achieved. Four cores were cut according to AASHTO T 24. Core strengths were based on the best three out of four cores tested dry using sulfur caps without the AASHTO (L/D) ratio factor applied.

**B. Measured Properties from QC Tests of Production Concrete for Deck**

Cement Composition: —  
 Actual Curing Procedure for Deck: Soaker hoses under plastic coated wet burlap and plastic cover  
 Air Content, Slump,  
 and Compressive Strength:

Date Cast	Span	Location	Air Content, %	Slump, in	Compressive Strength, psi	
					7 days	28 days
11/15/99	5	Center	4.2	5	6180	7500
			4.0	6	5690	7000
11/16/99	6	Center	4.9	5-1/2	6430	7840
			5.7	5-3/4	5700	7010
11/18/99	7	Center	4.9	6-1/2	5000	6000
			3.8	6	5730	6700
11/19/99	5	North Quarter	4.5	7	6010	7100
11/22/99	6	South Quarter	4.2	5	5780	6840
11/23/99	6	North Quarter	5.0	5	5860	6970
11/24/99	7	North Quarter	4.5	5-1/4	5620	7140
11/29/99	7	South Quarter	5.1	6-3/4	5120	6510
11/30/99	5	South Quarter	4.9	5-1/2	5860	7360
12/2/99	4	Center	5.9	6	5720	6900
			4.8	5-1/4	5470	7300
12/6/99	3	Center	4.0	5-1/2	5760	8280
			5.1	6	6560	7760
12/7/99	4	North Quarter	5.3	5-1/2	5640	7100
12/8/99	4	South Quarter	5.6	5-1/2	5820	7070
12/14/99	2	Center	4.6	5	6600	8000
			4.6	6	6640	7950
12/15/99	1	Center	4.6	5-1/2	6570	8180
			4.3	6	6830	7540
12/16/99	3	North Quarter	4.9	6	6600	8140
12/16/99	3	South Quarter	3.7	5-1/2	6670	8200
12/20/99	2	South Quarter	5.3	6	6320	7560
12/22/99	2	North Quarter	6.2	6	5920	6960
12/23/99	1	South Quarter	5.0	5-1/2	6240	7700
12/23/99	1	North Quarter	3.25	5-1/2	6060	7790
Average			4.7	5-3/4	6010	7370

Curing Procedure for Cylinders: —

**C. Measured Properties from Research Tests of Production Concrete for Girders**

Unit Weight: 149.7 lb/ft<sup>3</sup>  
 Compressive Strength:  
 (AASHTO T 22)

Pour No.	Curing Method (7)	Compressive Strength (8), psi			
		Release	7 days	28 days	56 days
1	(A)	8940	9780	10,050	11,280
	(D)	8100	9130	9750	10,100
	(E)	—	—	10,130	11,020
2	(D)	8080	8680	9270	—
3	(A)	—	—	—	10,750
	(D)	8320	9530	10,600	12,290
4	(D)	—	8690	10,300	10,810
5	(A)	—	—	11,000	10,850
	(D)	7060	9470	10,460	10,240
6	(A)	—	—	—	9270
	(D)	7760	8870	10,520	10,410
7	(D)	7720	9030	—	—
8	(B)	8950	—	10,480	10,150
	(D)	7480	8910	9890	10,360
9	(A)	—	—	—	9990
	(D)	7520	8790	9470	10,540
10	(A)	—	—	11,090	10,350
	(D)	8200	9250	9910	10,380
11	(A)	—	—	10,550	10,250
	(B)	—	—	10,410	10,230
	(C)	—	—	10,650	—
	(D)	—	9390	9930	—
12	(A)	—	—	9950	10,150
	(C)	—	—	10,050	11,240
	(D)	—	8780	8990	—
13	(A)	—	—	11,270	11,350
	(D)	8990	10,130	10,960	11,580
14	(A)	—	—	10,760	11,060
	(C)	—	—	12,070	12,640
	(D)	8870	10,180	10,920	11,850
15	(A)	—	11,110	12,300	12,230
	(D)	8730	9810	11,600	11,620
16	(A)	—	—	11,620	11,540
	(B)	—	—	10,630	11,540
	(C)	—	—	13,030	13,650
	(D)	8440	9770	11,380	11,400

17	(A)	—	12,280	11,880	12,190
	(D)	9390	10,300	11,080	11,540
18	(A)	9950	—	11,320	12,370
	(D)	9750	10,920	11,290	12,010
Average	(A)	9450	11,060	11,070	10,970
	(B)	8950	—	10,510	10,640
	(C)	—	—	11,450	12,510
	(D)	8290	9420	10,370	11,080
	(E)	—	—	10,130	11,020

- (7) (A) 4x8-in Sure Cure cylinders followed by curing in the casting yard.  
 (B) 4x8-in Sure Cure cylinders followed by curing indoors.  
 (C) 4x8 in Sure Cure cylinders followed by curing in a limewater bath.  
 (D) 4x8-in standard cylinders made in plastic molds and cured under the tarpaulin and then cured in the casting yard.  
 (E) 4x8-in. cylinders cured according to ASTM C 31.
- (8) All cylinder tests performed using 70 durometer neoprene pads.

Modulus of Elasticity:  
(ASTM C 469)

Pour No.	Curing Method (9)	Modulus of Elasticity (10), ksi			
		Release	7 days	28 days	56 days
1	(A)	5900	6600	6000	5900
3	(A)	—	—	—	6000
4	(A)	—	—	—	4300
	(D)	—	—	—	6150
5	(A)	—	—	—	4400
6	(A)	—	—	—	5350
8	(A)	—	—	5600	5600
9	(B)	5400	5600	5450	5900
10	(A)	—	—	5300	5400
	(D)	—	—	5500	5050
13	(A)	—	—	5200	6000
14	(A)	—	—	—	5800
15	(A)	5250	—	5800	5300
16	(A)	—	—	6300	5800
17	(A)	5300	—	7100	7000
18	(A)	—	—	6500	6900

- (9) (A) 4x8-in Sure Cure cylinders followed by curing in the casting yard.  
 (B) 4x8-in Sure Cure cylinders followed by curing indoors.  
 (D) 4x8-in standard cylinders made in plastic molds and cured under the tarpaulin and then cured in the casting yard.
- (10) Results are for one cylinder test.

Splitting Tensile Strength:  
(AASHTO T 198)

Pour No.	Curing Method (11)	Splitting Tensile Strength (12), psi		
		Release	28 days	56 days
1	(A)	590	650	—
3	(A)	—	—	700
4	(D)	—	—	800
5	(A)	—	—	700
6	(A)	—	—	660
8	(B)	650	700	740
9	(A)	—	—	550
	(A)	—	—	600
10	(A)	—	740	600
	(D)	—	650	600
13	(A)	—	600	650
	(A)	—	—	700
14	(A)	—	—	650
15	(A)	600	700	700
	(A)	—	—	650
16	(A)	—	650	840
17	(A)	—	600	—
	(A)	640	700	800
18	(A)	—	720	810

- (11) (A) 4x8-in Sure Cure cylinders followed by curing in the casting yard.  
 (B) 4x8-in Sure Cure cylinders followed by curing indoors.  
 (D) 4x8-in standard cylinders made in plastic molds and cured under the tarpaulin and then cured in the casting yard.
- (12) Results are for one cylinder test.

Chloride Permeability:  
(AASHTO T 277)

Pour No.	Curing Method (13)	Charge Passed, coulombs	AASHTO T 277 Rating (14)
1	(A)	2140	Moderate
	(A)	2870	Moderate
	(E)	1920	Low
	(E)	2280	Moderate
5	(A)	3130	Moderate
	(D)	2290	Moderate
8	(A)	5610	High
	(A)	5730	High
	(D)	2710	Moderate
	(D)	2720	Moderate
10	(B)	2530	Moderate
	(B)	2600	Moderate
	(D)	2690	Moderate
	(D)	2730	Moderate
13	(A)	2220	Moderate
	(A)	2120	Moderate
	(D)	2470	Moderate
	(D)	2530	Moderate
15	(A)	2400	Moderate
	(A)	2210	Moderate
	(D)	2340	Moderate
	(D)	2370	Moderate
17	(A)	2340	Moderate
	(D)	2370	Moderate
Average		2720	Moderate

- (13) (A) 4x8-in Sure Cure cylinders followed by curing in the casting yard.  
 (B) 4x8-in Sure Cure cylinders followed by curing indoors.  
 (D) 4x8-in standard cylinders made in plastic molds and cured under the tarpaulin and then cured in the casting yard.  
 (E) 4x8-in cylinders cured according to ASTM C 31.  
 All tests were made at a concrete age of 56 days.
- (14) Refer to table 1 in AASHTO T 277.



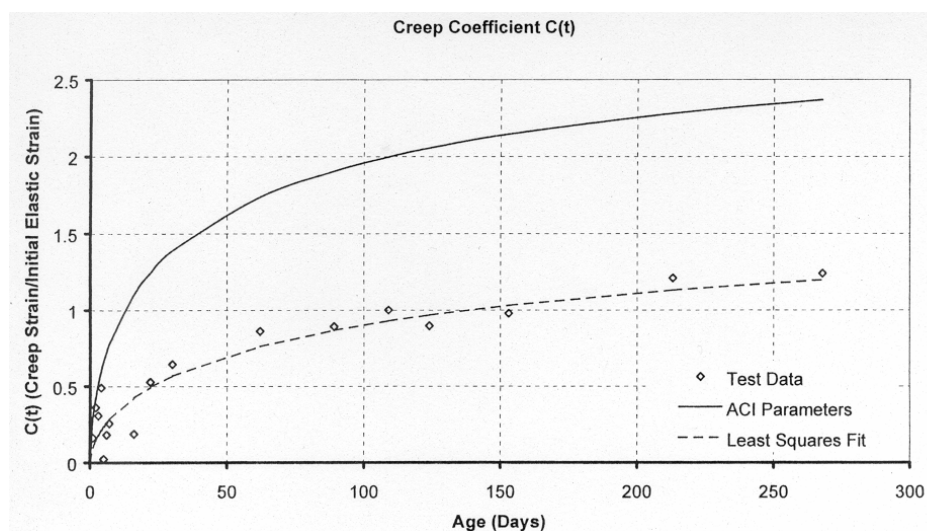
Freeze-Thaw Durability:  
(AASHTO T 161, Procedure A)

Pour No.	Initial Frequency, Hz	Final Frequency, Hz	Durability Factor, %
1	2500	2450	96.0
	2460	2450	99.2
	2470	2440	97.6
Average			97.6
10	2530	2510	98.4
	2530	2490	96.9
	2540	2520	98.4
Average			97.9
16	2580	2560	98.5
	2590	2560	97.7
	2580	2560	98.5
Average			98.2

3x4x16-in specimens cured in a limewater bath for 14 days prior to start of the test.

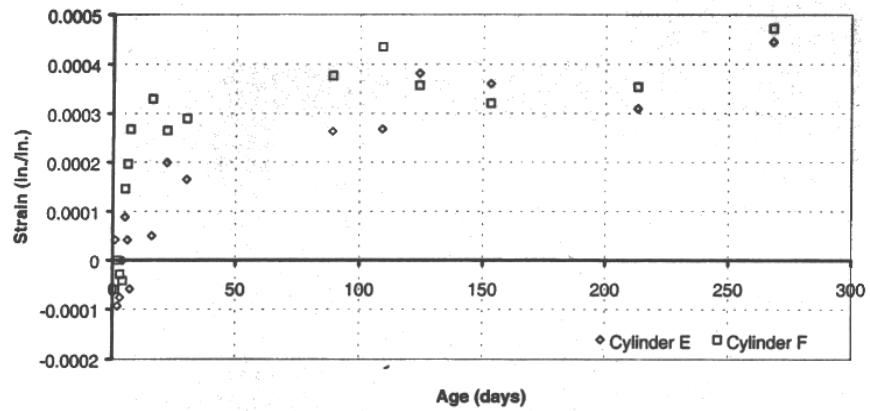
Tests were conducted for 300 freeze-thaw cycles with three samples per mix.

Creep (15):  
(ASTM C 512)



(15) Measured on 4x8-in match-cured cylinders loaded at 24 hours to approximately 45 percent of the measured compressive strength. Creep coefficient is based on an elastic strain of 691 millionths.

## Shrinkage (16):



(16) Measured on 4x8-in match-cured cylinders starting at age of 24 hours.

## D. Measured Properties from Research Tests of Production Concrete for Deck

Data were obtained from concrete used on the deck of Uphapee Creek Relief Bridge, which used the same concrete mix proportions as the concrete for the deck of the bridge over Uphapee Creek.

Slump and Air Content:

Span	Slump, in	Air Content, %
4	4-1/2	3.6
6	5-1/4	4.7
3	4	3.9

Compressive Strength, Modulus of Elasticity,  
Tensile Strength, and Chloride Permeability:

Span	Age, days			
	7	28	56	91
Compressive Strength (17), psi				
4	5810	7440	8220	8630
6	5280	7220	7440	7870
3	5170	6450	6940	7370
Modulus of Elasticity (18), ksi				
4	4650	6500	6600	7300
6	4050	5750	5350	6600
3	4800	4950	5050	6050
Splitting Tensile Strength (19), psi				
4	440	530	520	490
6	410	530	490	560
3	350	470	490	430
Chloride Permeability (20), coulombs				
4	—	—	2835	1995
6	—	—	2765	1960
3	—	—	3020	2085

(17) AASHTO T 22. Average of three 6x12-in cylinders stored on site for 24 hours and then placed in a moist room and tested with neoprene caps.

(18) ASTM C 469. One 6x12-in cylinder cured in same manner as the compressive strength cylinders.

(19) AASHTO T 198. Average of two 6x12-in cylinders cured in the same manner as the compressive strength cylinders.

(20) AASHTO T 277. Average of two 2-in-thick slices cut from 4x8-in cylinders cured in the same manner as the compressive strength cylinders.

Freeze-Thaw Durability:  
(AASHTO T 161, Procedure A)

Spans	Initial Frequency, Hz	Final Frequency, Hz	Durability Factor, %
4	2340	2230	90.8
	2350	2170	85.3
	2350	2250	91.7
Average			89.3
6	2270	2170	91.4
	2270	2160	90.5
	2260	2200	94.8
Average			92.2
3	2320	2230	92.4
	2320	2220	91.6
	2330	2220	90.8
Average			91.6

3x4x16-in specimens cured in a limewater bath for 14 days prior to start of the test.

Tests were conducted for 300 freeze thaw cycles with three samples per mix.

Abrasion Resistance (21): 0.00195 oz/in<sup>2</sup>  
(ASTM C 944)

(21) 6x16x2-in specimens water cured for 7 days followed by curing in air until a concrete age of 56 days. Test used a 22 lb force at 200 rpm for a two-minute abrasion period. The test result is mass loss per unit area.

Shrinkage:

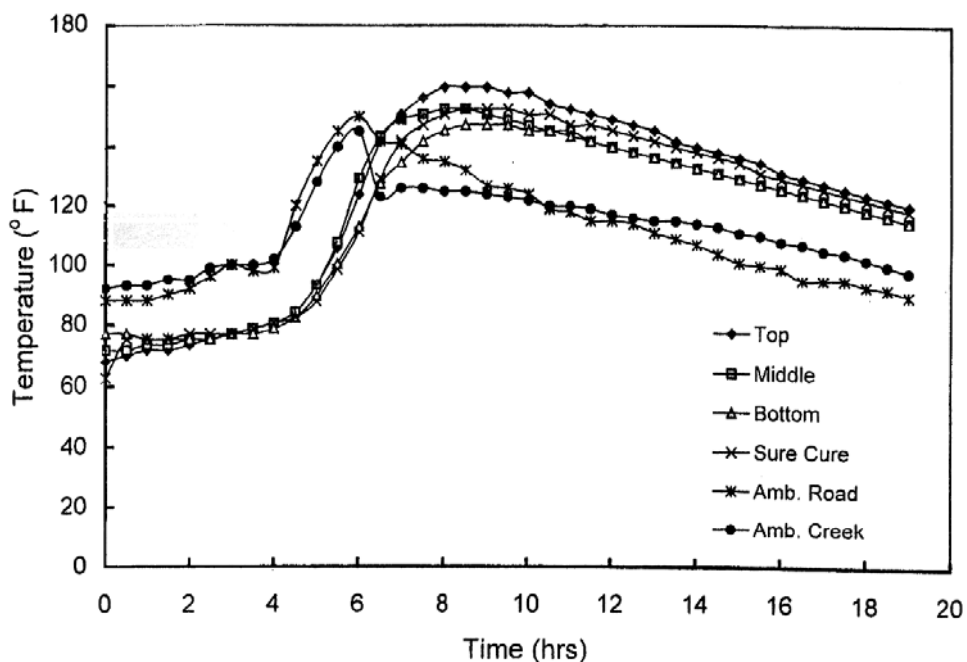
Span	Curing Period, days	Shrinkage (22), millionths
4	7	470
	28	280
6	7	480
	28	330
3	7	250
	28	300

(22) ASTM C 157 using 3x3x12-in prisms. Zero length was measured when the specimens were stripped from the molds at 1 day and before immersing in lime water. Values are reported for a concrete age of 90 days.

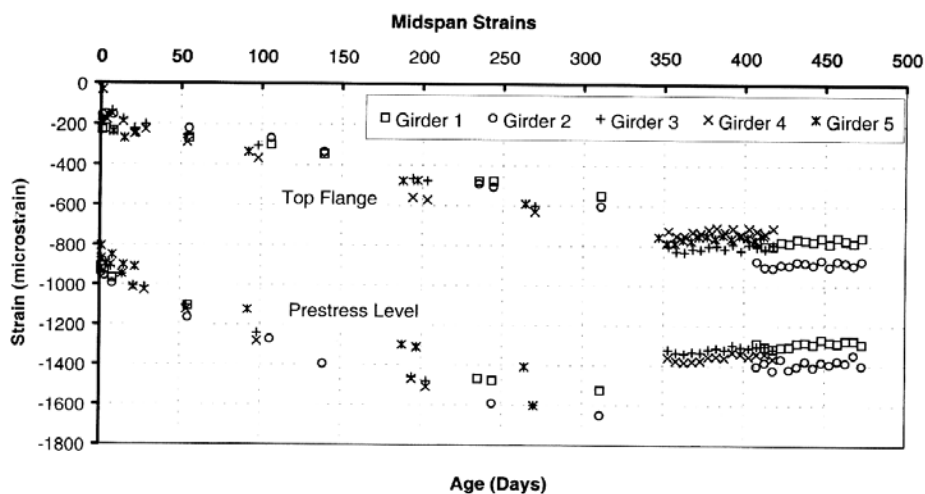
## 7. OTHER RESEARCH DATA

### Temperature:

Similar plots for each pour are available in the final report referenced in section 9. See section 10 for locations of thermocouples in the girder cross section.



### Strains (23):



(23) Strains were measured in the top and bottom flanges of five girders in one span. See section 10 for location of gages in the girder cross section.

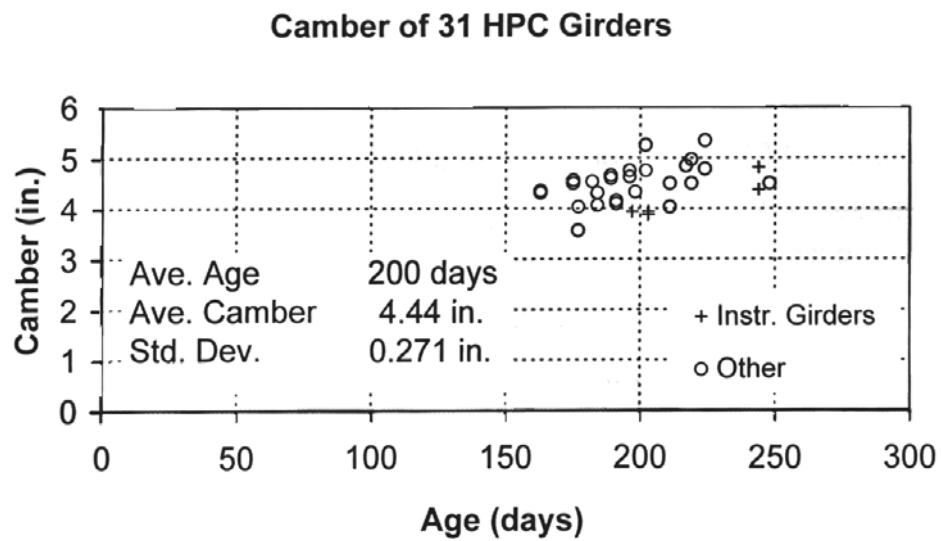
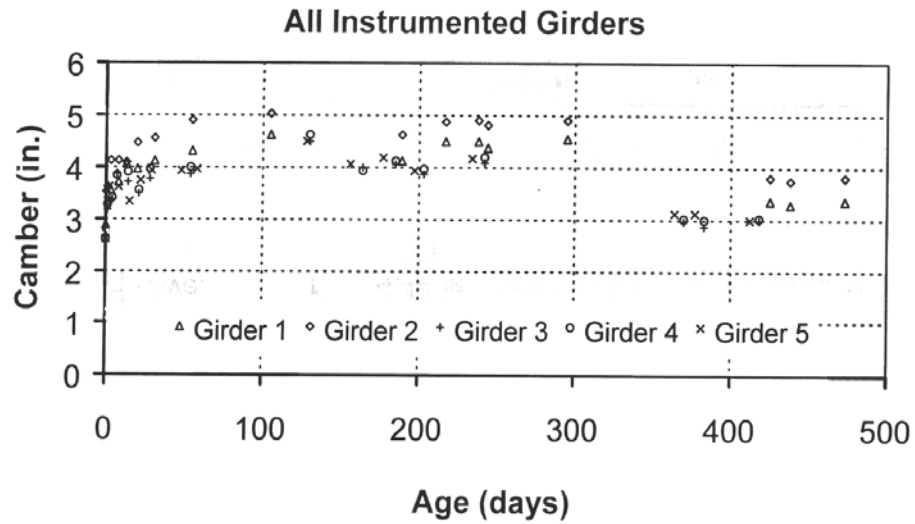
## Prestress Losses:

Girder No.	Final Age (24), days	Measured Losses (25), psi	
		Midspan	Quarter Span
1	311	16,910	—
2	311	19,440	—
3	270	20,240	18,150
4	270	20,210	17,550
5	264	16,560	14,900

(24) Prior to casting of the deck.

(25) Losses are reported as values occurring after 1 day and do not include strains at release.

Camber:



## 8. OTHER RELATED RESEARCH

Prior to casting the production girders, a test pour was made using a 10-ft-long section of a BT-63 girder. During the test pour, concrete cylinders were cast to investigate the effects of cylinder size, initial and final curing conditions, and cylinder capping methods. In addition, concrete cores were obtained from the girder and used to evaluate the effects of different procedures. Test results are given in the following tables.

Effect of Cylinder Size and  
Different Curing Conditions:

Cylinder Size	Curing (26)		Concrete Age, days				
	Initial	Final	Release (27)	7	14	28	56
Compressive Strength (28), psi							
4x8 in	CMC	Air	10,170	—	11,320	11,420	13,150
	Match	Air	9970	10,800	10,930	11,550	11,820
	Tarp	Air	10,060	—	12,210	12,150	—
	ASTM	Lime	8780	10,550	11,380	12,440	13,580
6x12 in	CMC	Air	9500	—	10,370	11,120	—
	Match	Air	8520	—	—	10,390	—
	Tarp	Air	9010	—	11,090	10,750	—
Modulus of Elasticity, (29), ksi							
4x8 in	Match	Air	6500	—	—	6650	—
	ASTM	Lime	6500	—	—	8100	—
6x12 in	Match	Air	6700	—	—	7050	—
Splitting Tensile Strength, psi							
4x8 in	Match	Air	860	—	—	—	—
	ASTM	Lime	630	—	—	—	—
6x12 in	Match	Air	670	—	—	—	—

(26) CMC – Contractor's match cure system consisting of an insulated 3x4-ft box with heater and controller.

Match – Researcher's match cure system.

Tarp – Cylinders cured under the tarpaulin with member.

ASTM – Cylinders cured according to ASTM C 31.

(27) Release time was 24 hours.

(28) Compressive strength tests were made using neoprene pads with a durometer hardness of 70.

(29) Results of one cylinder.



Effect of Final Curing Conditions on  
Compressive Strength (30):

Curing (31)		Test Age, days		
Initial	Final	7	28	56
Tarp	Air	11,670	11,110	11,760
	Moist	10,680	11,510	12,910
	Lime	11,220	11,490	12,630

(30) All results are the average compressive strength of two 4x8-in cylinders tested using neoprene pads with a durometer hardness of 70. Units are psi.

(31) Tarp – Cylinders cured under the tarpaulin with member.

Air – Cylinders cured in the casting yard.

Moist – Cylinders cured at 90 to 95% RH and 70 to 75 °F.

Lime – Cylinders in a limewater bath at 70 to 74 °F.

Effect of Cylinder Capping Method on  
Compressive Strength (32):

Cylinder Size	Curing (33)		Capping Method (34)	Concrete Age, days			
	Initial	Final		Release (35)	7	14	28
4x8 in	CMC	Air	Neoprene	10,170	—	11,320	11,420
			Sulfur	8990	10,340	10,340	10,940
	Tarp	Air	Neoprene	10,060	—	12,210	12,150
			Sulfur	9210	—	10,430	11,640
6x12 in	CMC	Air	Neoprene	9500	—	10,370	11,120
			Sulfur	9020	9950	10,300	10,580
	Tarp	Air	Neoprene	9010	—	11,090	10,750
			Sulfur	8390	10,620	10,240	10,550

(32) All results are the average of two cylinders. Units are psi.

(33) CMC – Contractor's match cure system consisting of an insulated 3x4-ft box with heater and controller.

Tarp – Cylinders cured under tarpaulin with member

Air – Not defined but assumed to be cured in the casting yard.

(34) Neoprene – 70 durometer hardness neoprene pads.

Sulfur – high strength sulfur capping compound.

(35) Release time was 24 hours.

## Core Compressive Strength, psi:

Test Procedure (36)	Specimen	Concrete Test Age, days			
		28	30	35	56
A	Core	11,770	10,660	12,030	12,680
B	Core	—	11,470	—	—
C	Core	—	—	12,990	—
D	Cylinder	11,550	11,760	11,860	11,820

(36) All cores were approximately 3.8x6.2 in obtained in accordance with AASHTO T 24. No correction for l/d ratio has been made.

Procedure A consisted of cutting and testing cores on the same day.

Procedure B consisted of cutting cores and soaking in a limewater bath for 48 hours prior to test.

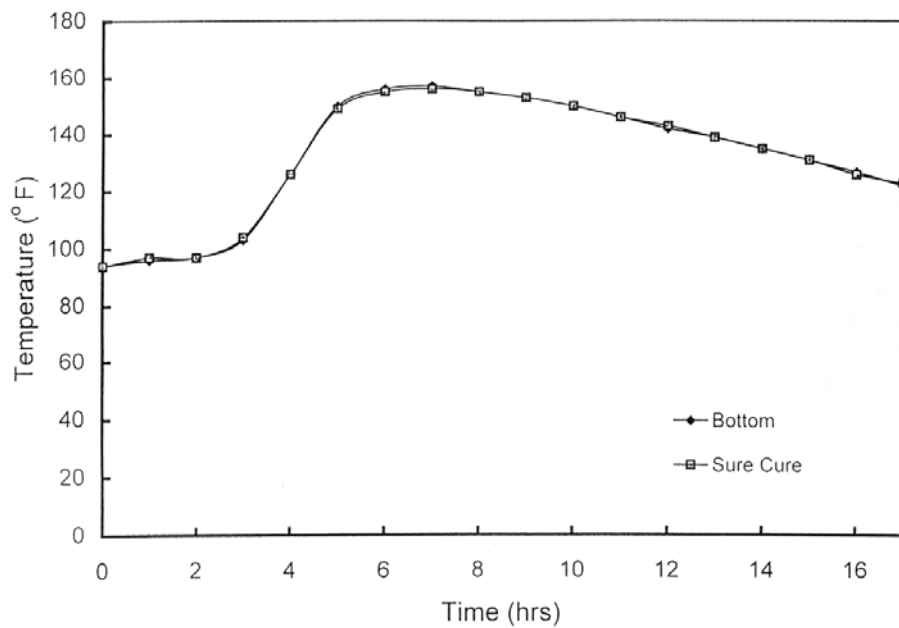
Procedure C consisted of cutting cores and air drying for 7 days prior to test.

Procedure D consisted of match-cured cylinders.

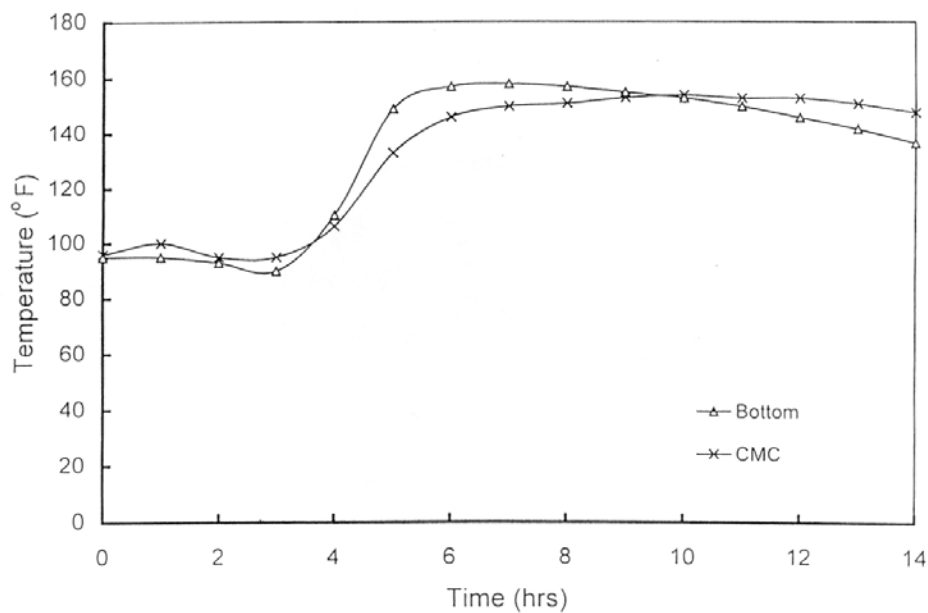
Core compressive strengths are the average of the highest 3 out of 4 results.

Tests were made using 70 durometer hardness neoprene pads.

## Test Cylinder Temperatures:



Sure Cure Match Cure System



Contractor's Match Cure System

Concrete temperature histories of two drilled shafts and two bent caps were measured. The concrete in the drilled shafts was not HPC. The concrete in the bent caps was HPC. Results are included in the report by Glover and Stallings listed in section 9.

According to the report by Glover and Stallings, the decks exhibited regularly spaced transverse deck cracks within 90 days of completion of the deck pours.

## **9. SOURCES OF DATA**

Stallings, J. M. and Eskildsen, S., "Camber and Prestress Losses in High Performance Concrete Bridge Girders," Highway Research Center, Harbert Engineering Center, Auburn University, Auburn, AL, May 2001, 116 pp.

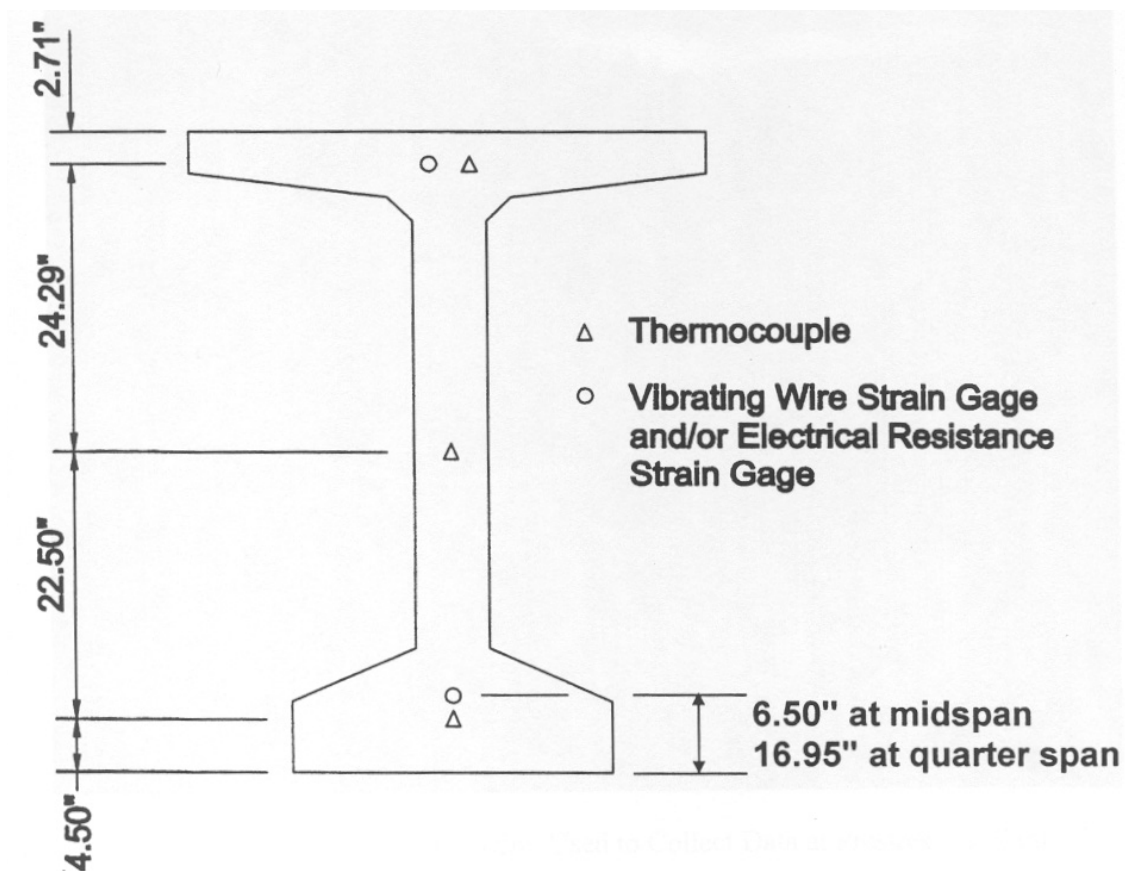
Glover, M. J. and Stallings, J. M., "High-Performance Bridge Concrete," Highway Research Center, Harbert Engineering Center, Auburn University, Auburn, AL, June 2000, 360 pp.

Southeast Regional High Performance Concrete Showcase Notebook, Auburn, AL, June 29-July 1, 1999.

Rodriguez, S., "Concrete Specification Requirements for Alabama's HPC Bridge," HPC Bridge Views, Issue No. 9, May/June, 2000, pp. 3.

William F, Conway, Alabama Department of Transportation, AL.

J. Michael Stallings, Auburn University, Auburn, AL.

**10. DRAWINGS**

Instrumentation Locations

## **11. HPC SPECIFICATIONS**

Not available.